Complex parts machining with five-axis machines grows more popular

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Following the money trail is a police-drama honored way of sorting out the usual suspects in solving a crime. Keeping an eye on the money is also a good strategy for shops looking to remain competitive, as well as a bigger payday.

Today, adopting five-axis machine technology is a tried and true method of producing more complex workpieces with higher value in both the raw and the machined states. A starting point for the value of an aerospace-intended casting for a jet engine might be as much as $400,000 before adding value with machining, for example.

Orders for five-axis machines are on the rise as shops migrate from three-axis and four-axis vertical and horizontal platforms to technology that can produce higher value complex workpieces for aerospace machined from difficult-to-machine alloys, titanium, Inconel, and aluminum. It’s not as if five-axis machining hasn’t been around for some time. Rather the emergence of strong demand from the commercial aircraft industry has motivated shops to pursue the higher rewards attached to five-axis machined parts.
Five-Axis Machining Challenges Shops’ Core Competencies

“By moving into five-axis machining, shops limit the number of horizontals that they need and are able to take on more complex components that have higher value and, most important, higher machine rates,” said Scott Walker, president, Mitsui Seiki USA Inc. (Franklin Lakes, NJ). Five-axis machines process parts efficiently, take up less shop-floor space—with one five-axis machine typically replacing three horizontals—and can double shop machine rates.

“With most five-axis machined parts fitting into a 500-mm cube or less, the majority of five-axis machines purchased by job shops are vertical machines. Our most popular five-axis machine is the Mitsui Seiki HU 63 five-axis horizontal with a 630-mm table and 950-mm swing, especially for machining precision aerospace workpieces,” said Walker.

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When a job shop migrates to five-axis machining, its core competency and engineering philosophy needs to be upgraded in every aspect of their operations including personnel training, processes, software and CNC controls. “One of the first questions I ask shops is how toolpath is going to be generated. Five-axis machining requires sophisticated CAD/CAM software like that used typically by aerospace and tool and die shops,” said Walker. “Other requirements include collision software, probing macros written for five-axis machining and tool breakage detection systems. We’ve developed five-axis probing routines on a Fanuc-based CNC specific to trunnion machine design as have Heidenhain and Siemens.”

Shops will have to add significantly more tools for five-axis applications. “Typically, five-axis applications require a minimum of 180 tools and that’s for the simple parts. Not only do you want redundancy in there, but there are so many more features to be machined on a five-axis part versus a three-axis part,” said Walker. “Machine diagnostics to avoid unnecessary downtime and anything that adds intelligence to the machine to minimize possible operator intervention are all highly desirable.”

Additive/Subtractive Combined in a Five-Axis Hybrid Machine

With a great deal of fanfare, additive/subtractive technology has been added to a five-axis machine platform on the Lasertec 65 3D hybrid from DMG MORI (Hoffman Estates,
Innovative Workholding for Five-Axis Machining

Workholding is a key element of any metal cutting operation because it influences dimensional accuracy, surface quality and total process time. Five-axis machining combines movement of X, Y and Z linear axes with A and B rotary axes to permit five sides of a part to be machined without refixturing. With it, shops can machine part features in precise relation to each other and save the time that would otherwise be required to refixture the part for sequential machining of multiple sides. Plus, full simultaneous five-axis machining makes easy work of complex contours that otherwise would be extremely difficult, if not impossible, to machine.

However, fully exploiting the benefits of five-axis technology involves special considerations. Users must write complex toolpath programs and choose optimal cutting tools. Then, simply holding the workpiece provides significant challenges. Machining multiple sides of a part requires the spindle to move throughout the machine’s work envelope, and deep features demand the use of long-reach tools.

To provide sufficient room for spindle movement and tool clearance, workholding must be as compact as possible and also position the part high enough above the table so that tools can reach all necessary features. Typically, to achieve this, shops will mount a vise on custom-machined riser plates to enhance spindle and tool access, but such plates can compromise rigidity and degrade dimensional accuracy as well as surface finish. Engineering and machining the plates also consumes time and money.

Productivity issues exist as well. For top efficiency, workholding equipment must be able to grip a wide variety of parts but still permit quick setup and changeovers without a need for expensive custom fabrication of clamping devices.

To address the challenges of five-axis machining, Röhm Products of America (Lawrenceville, GA) developed the RZM centric clamping vise system engineered with as small a footprint as possible and bodies that position workpieces for maximum tool and spindle access on all five sides. The special RZM jaws telescope into one another in a patent-protected method that adds stability and rigidity and provides centering within 20 µm and safe part machining with up to 900 N•m material strength. The vise base is a precision-ground, hardened-steel rail, with cylindrical recess for a center locating pin and grooves for precise alignment with the T slots in the machine tool’s worktable.

Because chip accumulation can hinder five-axis machining operations, the RZM’s clean interior and exterior surfaces are smooth for problem-free chip and coolant evacuation. This greatly minimizes, if not eliminates, the need to stop the machining process for cleaning and clearing away chips—especially beneficial for untended operations. Plus, the vise’s jaw-adjustment screw is located high on the vise body for easy access and to further streamline chip evacuation.

A variety of jaw styles for the RZM enhance flexibility of application and speeds changeovers. Flat jaws are suited for a range of simple parts, while claw and serrated jaws provide added grip. Jaws are available for horizontal or vertical setups, and for holding round pieces of material. SNF jaws feature a spring plate that provides a drawdown action. Jaws allow for installation of an adjustable workpiece locator stop to ensure repeatability when machining a series of similar parts. The vises are supplied with SKB claw jaws that provide a tighter hold with less force and minimal material loss.

RZM vises come in two versions engineered to handle a wide range of part sizes. The long version with a base rail length of 260 mm has a maximum jaw capacity of 222 mm. The short version with a 180-mm long base rail has jaw capacity of 141 mm. The height of both versions is 196 mm.

RZM centric clamping vise.
The machine incorporates generative laser deposition welding with a fully-capable five-axis milling machine. The thrust of the new hybrid is to provide a way to produce new products more quickly to meet the trend toward shorter life cycles and more complex and individualized components. The Lasertec 65 3D hybrid builds up workpieces with laser deposition welding of powders delivered by nozzle with a deposition rate of up to 2.2 lb/hr (1 kg/hr) that is said to be up to ten times faster than generation in a powder bed. Metal removal for finishing is performed by a five-axis milling head, though the additive technology can be added to other DMG MORI metal removing machine platforms.

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The Lasertec 65 is designed to expand the application of additive/subtractive technology from production of prototypes and small parts which couldn't be otherwise manufactured using conventional methods to manufacturing or repairing larger workpieces. To enable generative manufacturing, the Lasertec 65 3D is equipped with a 2-kW diode laser for laser deposition welding, while the five-axis milling machine features DMG MORI’s robust monoBLOCK design making it possible to carry out highly accurate milling operations. Change-over between milling and laser operation is automatic, making the Lasertec 65 3D suitable for the complete machining of complex components with undercuts as well as for repair work and the application of partial or complete layers of metal for moldmaking, engineered and medical workpieces.
Software Functionality is Enhanced in Advanced CNC

The Okuma OSP CNC control offers a full suite of five-axis functionality which has been enhanced with 3D cutter comp and tool center point control, according to Wade Anderson, product specialist sales manager, Okuma America Corp. (Charlotte, NC). “The transition to five-axis is a natural sequence as shops become comfortable adding a rotary table to a small three-axis vertical mill for the fourth axis, and then another rotary for the fifth axis. Five-axis machining provides the ability to get to five sides of a part and opens a lot of possibilities on how parts are processed, doing more work with less handling.”

Depending on the type of work that is done, fixturing for five-axis machining can be simple. “We do a lot of dovetail chucks where you have to cut the part to have a dovetail machined into it and then you grab that dovetail and that’s what you’re holding on to,” said Anderson.

Okuma’s new MU series of full five-axis machines, such as the MU-6300V and MU-8000V, utilizes a unique trunnion positioning on its five-axis machines that places it 90° from traditional machine setups. “There are two benefits,” said Anderson. “A pallet changer can come out of the back of the machine, eliminating interference with operator setup and access to the front door and controls. Another benefit is that negative machining angles are possible without a long spindle overhang,” said Anderson.

Okuma doesn’t offer scaled-down versions of its OSP CNC control. “We offer only one control that is used on our machines, we don’t have a scaled down version that limits you to four axis or 4+1. Our MU series of five-axis machining centers, with pallet sizes ranging from 400 to 1000 mm,” said Anderson, “are all full five-axis contouring OSP-P300S that has the functionalities of tool center point control and 3D manual feed mode. The control allows capabilities of programming the part through CAM systems by putting in vectors instead of rotary axes. The part can be moved from one trunnion-style Okuma machine to an Okuma with a B axis on the spindle and C on the table without reposting the part program. In the same way using the tool center point function, the part can be taken off the table and put back on to find the zero point on the part again from where the center line of the rotaries are and then offset the tool center point control without reposting,” said Anderson.

Two Mills In Unique Bridge-Style Combination

For machining composites and other aerospace materials, the P5 bridge-style five-axis mill from Bertsche Engineering Corp. (Buffalo Grove, IL) features a unique configuration in which two machining modules are hung on opposite sides of the bridge. Being on the opposite sides of the same bridge allows two different parts to be simultaneously machined at the same time.

To increase production capability the P5x5 machine features the two independent P5 mills packaged into the space of one P5 mill, essentially doubling the capacity per square foot of floor space occupied to meet production rates for the customer.

The P5x5 mill configuration has two completely independent five-axis (X-axis table and four axis on bridge) modules working in parallel with each other either making the same but more typically different parts. Each side runs its own program, has its own dedicated toolchanger, spindle probe, laser toolsetter, flood-coolant controls, machining compartment, auto part load door etc.

Two CNCs, one controlling A side and one controlling B side, operate the machine in one of three modes: A only mode; B only mode; and A&B mode. The two CNCs share information but either side runs independent of the other. One side can be serviced while the other side is machining parts. This allows production to continue even during PM periods.
CNC Control Smoothes, Speeds Five-Axis Machining

The Mazatrol SmoothX CNC technology introduced by Mazak Corp. (Florence, KY) at IMTS 2014 is part of a complete process performance technology platform that reaches across the entire part production cycle from programming to metal removal to automation and data collection. The technology comprises, in addition to the SmoothX CNC, new machine hardware and servo systems. Working together they are designed to tackle real machining challenges including cycle times, especially for simultaneous five-axis operations and free-form die-mold machining.

“We have run a five-axis machine with the previous generation Matrix 2 CNC five-axis code and then with the SmoothX CNC, and have seen drastic improvements just in the machine’s ability to interpolate code and send it to the machine tool servos in the shortest time,” said Michael Finn, development engineer. “The ability to read code at a higher rate is especially important in machining complex geometries like turbine blades, blisks, or any free-form surface that requires a higher point density,” said Finn.

To overcome the tendency of five-axis machining to be slower with longer cycle times, the Mazatrol SmoothX CNC ability to read code faster allows maintaining chip load in complex surface machining. “You need higher point density, where the machine changes direction and those are typically the leading and trailing edges on the blade. That’s where a lot of data points are required to keep the tool on track maintaining chip load so that it doesn’t fall away or gouge the workpiece. It’s important to have a CAM system that can prove-out programs with toolpath verification and collision avoidance. In the SmoothX CNC, you simply click on the area of the toolpath and it will highlight the code that applies, giving the user another important tool in his tool box,” said Finn.

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